INFLUENCE OF PLANTING METHODS ON THE VARIABILITY AND CORRELATIONS OF AGRONOMIC CHARACTERS IN THE F_2 POPULATIONS OF A *JAPONICA* RICE CROSS

by

W. L. CHANG*

INTRODUCTION

The pedigree method of handling segregating progenies of rice hybrids has been the standard breeding procedure for breeders in Taiwan. In recent years, however, rice breeders are becoming increasingly aware of the drawbacks associated with the pedigree system, even though most of the leading varieties since 1920 have been developed under this method. It is now known that many agronomic characters of economic importance are quantitively inherited and are readily influenced by environmental conditions. Therefore, in the early segregating generations, especially in the F_2, selection for these traits is not effective. If, however, F_2 populations are maintained in larger sizes, the efficiency of selection could be raised as better opportunities are given for the desired recombinants to be included in the populations. Unfortunately, rice breeders in Taiwan have only limited land area available for their segregating progenies and it is impossible to keep F_2's in large populations.

The bunch planting method provides an inexpensive means of carrying F_2 populations in adequate sizes than is generally possible in a conventional method of spaced planting. Should maximum genetic variance of important agronomic characters be obtainable in bunch-planted F_2 populations, selection under this condition would be more effective. The purpose of this investigation was to evaluate the genetic and environmental variability and correlations of some agronomic characters under the condition of bunch planting with the hope that information obtained may be useful to rice breeders.

REVIEW OF THE LITERATURE

The technique of planting hydrid seedlings in bunches was developed in 1935 in Hawaii for sugarcane breeding (Yang, 1957). It enables the breeders to carry populations in larger numbers. Selection under this condition has been reported to

*Agronomist, Chiayi Agricultural Experiment Station. The author wishes to express his appreciation to Dr. T. T. Chang, Geneticist, The International Rice Research Institute, for reviewing this paper and for his valuable suggestions. The author also wishes to thank L. Li, Agronomist, CAES, and C. H. Yu, Associate Professor, TPIA, for their statishical guidance in completing the analysis of this study.

be effective. At the same time, the cost of land and labor can also be reduced. Juang (1962) conducted an experiment to study the effect of bunch planting method on the selection of promising and vigorous sugarcane plants and concluded that this method may prove to be advantageous in Taiwan.

By planting seedlings of segregating F_2 population in bunches, the plants are subjected to intense competition. The assumtion is often made that high yielding plants survive better in a competitive population. Elliot (1958) cited a number of instances to show that in seed crops natural selection generally favored the high yielding genotypes.

It has been shown mathematically that the expected variance of any non-segregating population is largely environmental variance, thus the total variance of a segregating population would be composed of genetic variance and environmental variance. Apparently, the resulting F_2 variance contained two parts, the genotypic fraction due to genic action, including dominance and epistasis, and another fraction due to environment. Bartley and Weber (1952) interpreted Lush's definition of heritability in two ways. In the broad sense, heritability refers to the ratio of heritable variance to total variance. In the narrow sense, heritability is defined as the ratio of additive genetic variance to total variance.

Correlation between two characters has been generally calculated in three forms, i.e. genotypic correlation which has genetic relationship, environmental correlation with no genetic relation, and phenotypic correlation which combine both genotypic and environmental effects together. Dewey and Lu (1959) partitioned correlation coefficients into components of direct and indirect effects.

Recently, it has become recognized that the degree of heritability of a given character varies with growing conditions. Akemine and Kumagai (1958) reported that heritabilities and correlations of some agronomic characters in segregating generations of a rice cross changed with different time of planting. Heritability values in late planting were found to be higher than those of standard planting season. Gotoh and Osanai (1959) suggested that if a high estimate of a given character is obtainable under a particular set of conditions, the efficiency of selection for this character could be enhanced in this environment. Rumbaugh (1963) observed that the relationship between a component of yield and yield per plant altered as alfalfa plants were spaced closer together. Kariya and Yamamoto (1963) concluded that the best method for breeding rice varieties adapted to high planting density is to conduct selection under high planting density.

Matsuo (1956) reviewed the literature regarding the heritability of rice and found that heritabilities for plant type, plant height, number of grains per panicle and length of panicles are generally high while those of panicle weight and number of panicles are relatively low, especially in the early segregating generations. Bollich (1957) reported that heritability estimates for spikelet length and heading date in F_2 generation of a rice cross were 0.86 and 0.63, respectively. Grain yield had a low heritability value. The correlation coefficient of heading date and yield was

estimated at −0.61. Toriyama and Futsuhara (1958) reported that estimated heritability values were higher for heading date and culm height than for panicle number and panicle weight. Oung and Chang (1958) and Chang (1960) also reported higher heritability estimates for heading date and plant height than for tiller number in crosses of rice involving irradiated progenies and their parents. Nei (1960) observed that in two hybrid populations of rice studied, the heritability estimates for heading date and culm length were higher than those for grain yield and number of panicles per plant.

Heritability values for yield and other plant characters have also been reported for soybean (Weber and Moorthy, 1952; Yu, 1963), corn (Warner, 1952), barley (Grafius *et al.*, 1952; Fiuzat and Atkins, 1953; Jogi, 1956; Kiriyama and Konishi, 1956; 1957), wheat (McNeal, 1960), oat (Frey and Norden, 1959), *Lespedeza* (Cope, 1962) and tobacco (Chang, 1962).

MATERIALS AND METHODS

Choung-Chin-Chiu and Chianung 242, both of the *japonica* type, were used as parents and the cross was made in the second crop of 1962. The former was chosen for its high tillering capacity and the latter for its large and heavy panicles. Each parent was considered to be genetically homozygous. F_1 seeds were grown in the first crop of 1963 for productin of F_2 seeds.

In the second crop of 1963, F_2 plants and parents were grown in randomized complete blocks with three replications. F_2 seedlings were grown under two treatments, i.e. spaced planting and bunch planting. In the conventional method of spaced planting, the distance between rows was 25 cm and the distance between hills within a row was 20 cm. One seedling was planted to each hill. In the bunch planting method, a total of four seedlings were planted around the area where in conventional method a seedling should be transplanted. Four seedlings, each placed approximately 4.5 cm appart, formed a square in which one seedling occupied a corner of the square. Plantings of both parents were made in the same way as space-planted F_2. One hundred plants for each of the parents and two hundred plants for each planting of F_2 were included in each replication.

Twenty plants were selected at random from both parents and both treatments of F_2's in each replication and the following data were recorded for each plant: heading date, plant height, number of panicles per plant, number of grains per panicle, length of panicle, weight of panicle, weight of 100 grains and grain yield per plant.

Since F_2 plants and their parents were grown in three replications, replication differences were removd in the analysis of variance. The resulting F_2 variance, therefore, contained the genotypic and environmental portions. The average error mean squares of the parents for each of the eight characters studied were used as the environmental variance in computing F_2 genotypic variances. Similarly, environmental covariances were derived from parental plants. The F_2 genotypic variance

for each character studied was calculated by subtracting the environmental variance from the total (but adjusted for replication differences) F_2 variance.

In this experiment, heritability in the broad sense was calculated from the following formula:

$$\text{Heritability} = \frac{V_{F_2} - V_E}{V_{F_2}}$$

V_{F_2} = total F_2 variance observed.

$V_E = 1/2\ (V_{P_1} + V_{P_2})$, where V_{P_1} and V_{P_2} are total variance of parent 1 and parent 2 observed, respectively.

Phenotypic, genotypic, and environmental correlations between two characters were calculated from the following formulas:

$$r_P = \frac{COVxy_{F_2}}{\sqrt{Vx_{F_2} \cdot Vy_{F_2}}}$$

$$r_G = \frac{COVxy_{F_2} - COVxy_E}{\sqrt{(Vx_{F_2} - Vx_E)(Vy_{F_2} - Vy_E)}}$$

$$r_E = \frac{COVxy_E}{\sqrt{Vx_E \cdot Vy_E}}$$

r_P = phenotypic correlation coefficient.

r_G = genotypic correlation coefficient.

r_E = environmental correlation coefficient.

$COVxy_{F_2}$ = F_2 covariance between characters x and y.

$COVxy_E = 1/2\ (COVxy_{P_1} + COVxy_{P_2})$, where $COVxy_{P_1}$ and $COVxy_{P_2}$ are parent 1 and parent 2 covariances between characters x and y, respectively.

Vx_{F_2}, Vy_{F_2} = total F_2 variances observed in characters x and y, respectively.

$Vx_E = 1/2\ (Vx_{P_1} + Vx_{P_2})$, where Vx_{P_1} and Vx_{P_2} are total parent 1 and parent 2 variances observed in character x, respectively.

$Vy_E = 1/2\ (Vy_{P_1} + Vy_{P_2})$, where Vy_{P_1} and Vy_{P_2} are total parent 1 and parent 2 variances observed in character y, respectively.

A path-coefficient is simply a standardized partial-regression cofficient which permits the separation of the correlation coefficient into components of direct and indirect effects. In this paper, path-coefficients were calculated by following the abbreviated Doolittle method (Yeh, 1962).

EXPERIMENTAL PESULTS

Effect of Planting on the Character of F_2 Plants.

The means of eight agronomic characters measured are summarized in Table 1.

Table 1 shows that mean values for seven of the eight characters observed in bunch-planted F_2 plants were smaller than those of space-planted ones. The bunch planting greatly reduced the mean number of panicles, number of grains per panicle and grain yield per plant, but it caused only a slight reduction in heading date,

Table 1. Means of eight agronomic characters in the P_1, P_2, and F_2 plants of a rice cross, Choung-Chin-Chiu x Chianung 242

Characters	Choung-Chin Chiu(P_1)	Chianung 242(P_2)	F_2 space-planted	F_2 bunch-planted
Heading date (days)	56.42	61.30	53.05	52.28
Plant height (cm)	101.73	118.83	98.88	91.84
Number of panicles	12.35	7.42	10.85	4.82
Number of grains per panicle	75.55	133.20	82.82	59.29
Length of panicle (cm)	17.56	23.55	17.79	15.34
Weight of panicle (g)	2.08	3.62	2.23	1.52
Weight of 100 grains (g)	2.82	2.89	2.76	2.87
Grain yield per plant (g)	22.91	22.41	21.09	6.52

plant height and length of panicle, indicating that former characters were more easily affected by the environment than the latter ones. The average weight 100 grains in bunch planting was slightly higher than that of spaced planting, suggesting that this character was not affected by the change in planting method.

Estimates of Heritability.

Heritability in the broad sense for each character studied was calculated as the percent genotypic variance of the total F_2 variance. Table 2 shows the heritability estimates for eight characters of F_2 plants in the two planting treatments.

Table 2. Heritability estimates for eight agronomic character of F_2 plants in the spaced and bunch plantings.

Characters	Heritability (%)	
	Space-planted F_2	Bunch-planted F_2
Heading date	64.81	67.44
Plant height	61.38	68.28
Number of panicles	65.54	0
Number of grains per panicle	65.51	64.67
Length of panicle	61.17	78.50
Weight of panicle	31.90	42.50
Weight of 100 grains	50.57	38.57
Grain yield per plant	49.19	0

Heading date, plant height, number of grains per panicle and length of panicle showed comparatively high heritability values while those of weight of panicle and weight of 100 grains were relatively low. The heritability estimates for length of panicle, weight of panicle, plant height, and heading date increased by 17.33%, 10.60%, 6.90% and 2.63%, respectively under the condition of bunch planting. The heritabilities for weight of 100 grains and number of grains per head decreased by 12.00% and 0.84%, respectively when F_2 seedlings were

planted in bunches. Number of panicles and grain yield per plant in the bunch planting gave negative heritability values and these were replaced with 0.

Phenotypic, Genotypic, and Environmental Correlations.

Phenotypic, genotypic, and environmental correlations for all possible combinations are presented in Table 3.

Table 3 shows that genotypic correlations were, in general, higher than phenotypic correlations in both plantings of F_2 plants. Most of the phenotypic correlations of the bunch-planted F_2 plants were higher than those of the space-planted ones. Environmental correlations showed, on the whole, considerably smaller values than either the phenotypic or genotypic values to much larger for various character associations.

Genotypic and phenotypic correlation coefficients between any two characters had like signs in bunch planting. In the spaced planting, the positive phenotypic correlations between panicle length and weight of 100 grains, plant height and number of grains per panicle, and weight of panicle and weight of 100 grains became negative genotypic correlations, while the negative phenotypic correlation between heading date and grain yield per plant became positive genotypic correlation.

Phenotypic and environmental correlation were significant in most cases. For genotypic correlations, although appropriate tests of significance have not been developed, considerable variation in magnitude of the correlations was apparent. The highest positive phenotypic and genotypic correlations among the characters studied were found to be between number of grains per panicle and weight of panicle and between panicle length and heading date, respectively, while the highest negative phenotypic and genotypic correlations were obtained between number of panicles and weight of 100 grains, and between weight of 100 grains and grain yield per plant, respectively in the spaced planting. In the bunch planting, the highest positive correlations, both observed and genotypic, were found to be between panicle length and number of grains per panicle, while the highest negative phenotypic and genotypic correlations were obtained between heading date and weight of 100 grains and number of panicles and weight of 100 grains, respectively. For environmental correlations, number of grains per panicle and weight of panicle was most positively correlated, while heading date and grain yield per plant was most negatively associated.

Genotypic correlations between grain yield per plant and number of panicles and other attributes in bunch planting were not included because of the negative variances obtained for grain yield per plant and number of panicles in this planting treatment. The genotypic correlation coefficients involving panicle weight with several other characters exceeded unity in either the positive or negative directions. Hence, they were excluded from the table.

Path-Coefficient Analysis.

Four variables, i.e. number of panicles, number of grains per panicle, weight of

Table 3. Phenotypic, genotypic and environmental correlation coefficients between characters of space-and bunch-planted F_2 populations

Characters correlated	Correlation coefficients				
	Space-planted F_2		Bunch-planted F_2		r_E
	r_P	r_G	r_P	r_G	
Panicle length and					
plant height	0.6222**	0.6180	0.7323**	0.7770	0.6260**
heading date	0.5205**	0.9280	0.2941*	0.4668	−0.1721
number of panicles	−0.1734	−0.3607	0.1696	—	0.1502
number of grains per panicle	0.8219**	0.8796	0.9022**	0.9856	0.7244**
weight of panicle	0.8187**	—	0.8955**	—	0.6266**
weight of 100 grains	0.0065	−0.0962	−0.0646	−0.2078	0.0137
grain yield per plant	0.2875*	0.1586	0.6194**	—	0.4515**
Plant height and					
heading date	0.4838**	0.9244	0.3263**	0.6066	−0.2656*
number of panicles	0.0890	−0.0649	0.0742	—	0.3568**
number of grains per panicle	0.6610**	0.7069	0.8152**	0.9332	0.5828**
weight of panicle	0.5860**	0.6081	0.8146**	—	0.6183**
weight of 100 grains	−0.0768	−0.2049	−0.0763	−0.2224	0.0857
grain yield per plant	0.3608**	0.1922	0.7141**	—	0.5761**
Heading date and					
number of panicles	−0.2667*	−0.2608	0.1540	—	−0.2778*
number of grains per panicle	0.3731**	0.6999	0.3116*	0.5942	−0.2381
weight of panicle	0.3451**	—	0.3472**	0.8831	−0.2889*
weight of 100 grains	0.0120	0.1501	−0.6045**	—	−0.1775
grain yield per plant	−0.0170	0.2763	0.1122	—	−0.4092**
Number of panicles and					
number of grains per panicle	−0.0518	−0.2046	0.0323	—	0.2386
weight of panicle	−0.1028	−0.0375	−0.0530	—	0.1770
weight of 100 grains	−0.3227*	−0.4714	−0.2384	—	−0.1241
grain yield per plant	0.7402**	0.7099	0.5228**	—	0.8048**
Number of grains per panicle					
weight of panicle	0.9482**	—	0.8650**	0.9449	0.8200**
weight of 100 grains	−0.0583	−0.1653	−0.1465	−0.3773	0.0893
grain yield per plant	0.4399**	0.3107	0.7475**	—	0.6296**
Weight of panicle and					
weight of 100 grains	0.0962	−0.2873	0.3941**	0.4380	0.3647**
grain yield per plant	0.4151**	0.0646	0.7474**	—	0.6623**
Weight of 100 grains and					
grain yield per plant	−0.2820*	−0.6480	−0.1600	—	0.0823
Degree of freedom	58		58		58

* Correlation coefficients significant at the 5% level.
** Correlation coefficients significant at the 1% level.

100 grains, and grain yield per plant, were included in the path-coefficient analysis to partition phenotypic correlation coefficients. The interrelationships of (1) number of panicles, (2) number of grains per panicle, (3) weight of 100 grains, and (4) grain yield per plant are shown diagramatically in Figures 1 and 2 for space-and bunch-planted F_2 populations, respectively.

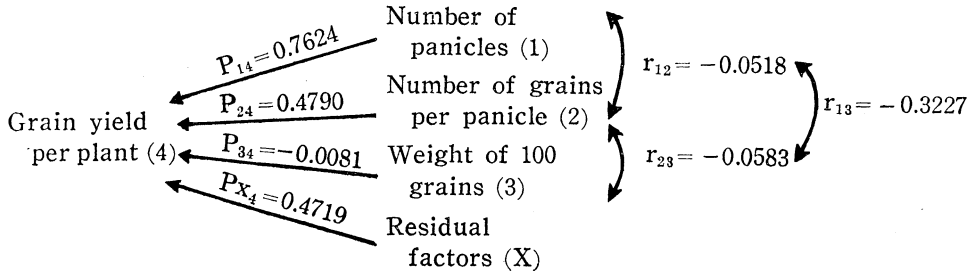

Figure 1. Path diagram and coefficients of factors affecting grain yield per plant in the space-planted F_2 population.

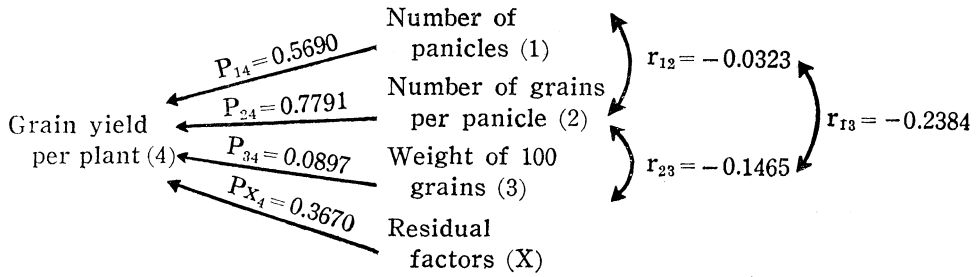

Figure 2. Path diagram and coefficients of factors affecting grain yield per plant in the bunch-planted F_2 population.

The double-arrowed lines indicate mutual association as measured by correlation coefficients. The single-arrowed lines represent direct effects in one direction measured by path coefficients. The residual variable (X) includes direct effects of all other factors affecting grain yield per plant in this experiment.

The diagrams shown in Figures 1 and 2 greatly facilitate the understanding of the nature of the cause and effect system. Figure 1 shows that the number of panicles was the most important agronomic character influencing grain yield per plant in the spaced-planting. The direct effect of unknown variables Px_4 was considerably high. Figure 2 reveals that the number of grains per panicle greatly influenced grain yield per plant in bunch-planted F_2 plants. The direct effect of unknown variables under the condition of bunch-planting was somewhat lower than that of the spaced one. Both diagrams indicate that the weight of 100 grains apparently had little to do with grain yield per plant in both plantings.

DISCUSSION

Heritability values for number of panicles and grain yield per plant were positive in the space-planted F_2 population, but they became negative in the bunch-

planted one because of their negative genotypic variances in the latter planting. It was found that in the bunch planting treatment, the ranges of variation for these two characters were much smaller than those of both parents. Consequently, the total observed variances of these two characters were smaller than those of parental means. The results indicated that variability of these two characters was highly susceptible to the masking or modifying effect of the bunch planting. A similar observation was also made by Karia and Yamamoto (1963). The other characters studied were comparatively less affected by the environmental factors. As a result, considerably higher heritability estimates were obtained for these characters, particularly in the bunch planting of F_2 population. The heritability estimates made in this experiment were, in general, similar to the results reported for rice (Bollich, 1957), barley (Fiuzat and Atkins, 1953), soybean (Yu, 1963), and many other crops.

In this experiment, a total of 60 plants each for both parents and the two plantings of F_2 were used for calculating environmental and phenotypic variances and covariance. The erratic and inconsistent heritability estimates for grain yield per plant and number of panicles seemed to indicate that more plants should be included for deriving heritability estimates, especially for the most variable attributes. Weber and Moorthy (1952) suggested that in soybean, 75 to 100 plants per parent would be more desirable for the estimates of heritability.

Under the condition of bunch planting, it was found that heritability values for length of panicle, plant height and heading date increased over those obtained under spaced planting, while those for number of panicles, grain yield per plant and weight of 100 grains showed a decrease. An increase in heritability value for plant height and a decrease for number of panicles in high planting density of rice plants were also observed by Kariya and Yamamoto (1963). Gotoh and Osanai (1959) reported that degree of heritability for a given character varies with growing conditions. Since degree of heritability is generally associated with efficiency of selection, the data seemed to indicate that effective selection could be made for certain characters under the conditions of bunch planting.

Heritability values for panicle length, plant height, heading date and number of grains per panicle were quite high in the bunch planting, suggesting that selection for these characters may be effective under this planting method. The genotypic correlation between panicle length and number of grains per panicle was positive and extremely high. From the examination of path-coefficients, it was revealed that number of grains per panicle was the most important character influencing grain yield per plant in bunch planting. In view of the extremely high positive association between panicle length and number of grains per panicle, and the decisive direct effect of number of grains per panicle upon the grain yield per plant, an indication seems to be that indirect selection for grain yield through panicle length could be an avenue for rapid progress. The positive and relatively high genotypic correlations between plant height and number of grains per panicle

would also be of value in individual plant selection for grain yield per plant.

In the space-planted F_2 population, number of panicles had the highest heritability value, indicating that selection for this character may be effective in this planting. It was observed that the number of panicles was highly and positively correlated with grain yield per plant. Path-cofficients showed that, in the spaced planting, grain yield per plant was determined primarily by the direct effect of panicle number. However, the high, positive association between panicle number and grain yield per plant probably would be of little value in selection because of generally low value of heritability found to be associated with number of panicles (Chang, 1960; Nei, 1960), and also the high positive environmental correlation coefficient observed between these two characters. Thus, the practice of indirect selection for grain yield through selection for panicle number does not appear promising.

The heritability for number of grains per panicle ranked next in the space-planted F_2 population. However, the genotypic correlation between number of grains per panicle and grain yield per plant was relatively low. The path-coefficients also indicated that, under the condition of spaced planting, the direct effect of number of grains per panicle on the grain yield per plant was only of secondary importance. As a result, the high association between number of grains per panicle and grain yield per plant may be of little practical value in selecting high yielding plants in the space-planted F_2 population.

The path-coefficient analysis indicated that the relationship of grain yield per plant with components of grain yield differed in the two plantings. Rumbaugh (1963) concluded that selection indices based upon yield component data obtained in spaced nurseris may not accurately portray the yield potentials of genotypes in solid seeding of alfalfa. Kariya and Yamamoto (1963) also reported that the best method for breeding rice varieties adapted to high planting density might be to conduct selection under the conditions of high planting density. It is apparent, therefore, that selection made in the bunch-planted F_2 population would contain more genotypes adapted to closely spaced growing conditions. Based on the observations of this study, a logical interpretation of the results seems to be that, under the conditions of this experiment, bunch planting appears to provide a favorable environment for effective selection of individual plants in the segregating F_2 population.

SUMMARY

Spaced and bunch plantings of F_2 plants of a cross between two *japonica* rice varieties, Choung-Chin-Chiu and Chianung 242, together with their space-planted parents, were arranged in randomized complete blocks to evaluate genetic and environmental variability of the segregating F_2 populations. Data recorded on each plant were heading date, plant height, number of panicles per plant, number of grains per panicle, length of panicle, weight of panicle, weight of 100 grains, and

grain yield per plant. Heritability values for each character and correlation coefficients between characters were calculated. Path-coefficient analysis was made to show the interrelationships of components of yield with grain yield per plant.

Bunch planting greatly reduced the average values of number of panicles and grain yield per plant, indicating that these characters were most easily affected by close spacing. The remaining characters studied were found to be less affected by the environmental variation. Means of weight of 100 grains in the two planting methods remained almost the same.

Heritability values for panicle length, weight of panicle, plant height, and heading date were higher in bunch planting than in the spaced one, while weight of 100 grains showed higher heritability value in spaced planting. The heritability estimates for the number of panicles and grain yield per plant were inconsistent in both plantings. Negative heritability estimates of these characters in bunch planting were due partly to the large environmental variance and partly to the unusually small phenotypic variance associated with these two characters.

Phenotypic correlations in bunch planting were found to be generally higher than those in spaced planting. Under each planting, genotypic correlations were mostly larger than phenotypic correlations. Positive associations involving number of grains per panicle with panicle length, plant height, and heading date were, in general, larger in bunch planting than those in the spaced one. Grain yield per plant was found to be highly correlated with number of grains per panicle in bunch planting, while in spaced planting, grain yield per plant was more closely associated with number of panicles.

From the examination of direct effects of components of yield on grain yield per plant, it was shown that the number of grains per panicle was the most important character influencing grain yield per plant in bunch planting, while in spaced planting, it was primarily the number of panicles that determined the grain yield per plant. Considering the magnitude of heritability and association of characters, it seems reasonable to conclude that bunch planting provides a more favorable environment for segregating F_2 populations in which effective individual plant selection could be made.

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移植法對水稻雜交第二代後裔農藝性狀變異及相關之影響

張　萬　來

摘　要

日本型水稻中京旭與嘉農 242 號品種雜交第二代後裔分別依慣行單本植法與檵植法移植以測定不同移植法對雜交第二代後裔主要農藝性狀變異及相關之影響。慣行單本植法行距爲 25 cm，株距 20 cm，每穴插植秧苗一支。檵植法之行，株距同前，惟在前法植穴周圍插植 4 支秧苗使成一檵，每檵內苗距 1 寸半見方，以防止生育後期檵內 4 單株之混雜。除 F_2 外，另加親本（單本植）參試，俾便估計環境變量。試驗設計採用隨機區組法，重複三次，每重複植株數，親本各爲 100 單株，單本植 F_2 200單株，檵植 F_2 200單株（卽50檵）。就每重複內各集團隨機選取 20 單株供爲生育日數，株高，穗數，每穗粒數，穗長，穗重，谷百粒重，及谷產量等農藝性狀之調查。根據調查結果計算各性狀廣義遺傳力及兩性狀間之各種相關係數。至於產量構成因子與谷產量間之相互關係則以路徑係數加以說明，玆將所得結果摘要如下：

主要農藝性狀之平均值，檵植區僅谷百粒重高於單本植區，餘外諸性狀多因檵植而行減少，尤以穗數與谷產量爲最，因此顯見，谷百粒重不受檵植影響，而穗數及谷產量對密植環境，特具敏感。

穗長，穗重，株高及生育日數之遺傳力，隨檵植而增加，但谷百粒重之遺傳力，却因檵植而減低，穗數與谷產量之遺傳力變化無常，其遺傳變量在檵植區變爲負值，其原因可能由於環境變量較大，與該性狀在檵植環境下其表現型變量大爲減低所致。

檵植區兩性狀間之表現型相關係數，多高於單本植區。在不同種植法之兩個集團，一般言之，遺傳型相關均高於表現型相關。每穗粒數與穗長，株高及生育日數等之相關，兩個 F_2 集團內均成極顯著之正相關，其相關係數，檵植區高於單本植區。在檵植區內，谷產量與每穗粒數之間有極顯著之正相關，而在單本植區，谷產量則與每株穗數成極顯著之正相關。

由路徑係數分析，得知檵植區內谷產量直接受每穗粒數之影響，而單本植區內，谷產量直接受每株穗數所牽制，綜合分析單本植與檵植區內 F_2 主要農藝性狀之遺傳力，相關係數與路徑係數，似可得一概念，卽在檵植環境下行單株選拔時可能獲得高產，優良個體之機會，似較在慣行單本植情形下選拔時爲大。